Simultaneous assessment of gallbladder emptying in the dog by real-time ultrasonography and strain gauge

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Abstract: Patterns of meal- and cerulein-induced gallbladder emptying (GBE) were compared in four dogs equipped with a force transducer implanted onto the body of the gallbladder, and in four unoperated animals. GBE was examined by real-time ultrasonography in conscious dogs. In two dogs the ultrasonographic measurement of GBE was performed simultaneously with the registration of the strain exerted on the force transducer fixed on the gallbladder body. Implantation of the force transducer on the gallbladder impaired neither postprandial nor cerulein-induced GBE. The contractile response of the gallbladder exhibited a nonlinear relationship to the gallbladder volume. The reduction of gallbladder volume to 50% of its basal value was accompanied by an increase in strain amounting to about 16% of the maximum response, whereas a pronounced augmentation of the strain was observed with gallbladder volume ranging between 30% and 10% of the basal value. On the other hand, the contractile response of the gallbladder registered by means of a force transducer was linearly related to the angle α contained between two radii passing from the gallbladder center towards the edges of the strain gauge: y = 0.852α - 30.97 (r = 0.959, P < 0.001) in the case of i.v. cerulein infusion at stepwisely increasing doses (0.7-2.2-7.4-22.2-66.5 pmol·kg⁻¹·h⁻¹), and y = 0.640α - 17.40 (r = 0.869, P < 0.001) for a 1-h constant-rate 22.2 pmol·kg⁻¹·h⁻¹ cerulein infusion.

Key words: gallbladder emptying, gallbladder volume, strain gauge, ultrasonography

Introduction

Studies of the pathophysiology of gallbladder (GB) contractility have become more and more extensive in recent years. Such studies have pursued elucidation of the role of deviated GB motility in the pathogenesis of gallstones and have attempted to elaborate (if possible) effective preventive measures against recurrence of the disease after removal of gallstones. Because of its anatomical similarity to that of humans, the biliary tract of the dog has often been used as an experimental model in studies examining GB motility. Up to now, however, only invasive methods have been used for the examination of GB volume and emptying, and the common feature of such methods is the requirement for surgical construction of a chronic GB fistula.¹² Recently, with the adaptation and validation in vivo for the use in dogs of an ultrasonographic method of measuring GB volume performed in our laboratory,³⁴ we have added a powerful noninvasive tool to the armamentarium of investigative methods available to examine canine GB contractility. Making use of the ultrasonographic method, our present study intended to answer whether, and to what extent, a force transducer implanted surgically onto the body of the GB would impair its contraction evoked by a meal or cerulein. The second aim of the study was to examine the relationship between changes in GB volume determined ultrasonographically during GB contraction induced by cerulein, and strain registered by a force transducer fixed on the GB body.

Methods

Eight mongrel dogs of both sexes, weighing, on average, 18kg (range, 15-23kg), were examined. The dogs were accustomed to remain immobile in a Pavlov stand for several hours. They received one standard meal a day...
(at 4.00 p.m.) and had free access to water. The examinations described here were performed on animals that were fasted for at least 18 h.

Ultrasonographic evaluation of GB emptying and refilling

A method developed originally by Dodds et al. and validated recently by us in vivo for use in dogs was applied. In brief, the calculation of GB volume \( V \) was based on an ellipsoid approximation of its shape:

\[
V = \frac{\pi}{6} \cdot L \cdot W \cdot H
\]

where \( V \) = GB volume; \( L \) = GB length; \( W \) = GB width; and \( H \) = GB height

The three dimensions of the GB were taken from its greatest longitudinal section \( (L) \), and from a cross-sectional image visualized perpendicularly to its long axis \( (W \) and \( H) \). Dogs were prepared by having the skin over the right thoracic area shaven and being placed immobile in a Pavlov stand. A real-time ultrasonographic unit \( \text{SAL} \ 32B \); Toshiba, Tokyo, Japan), equipped with a linear 5MHz transducer, was used to visualize the GB through the intercostal space. The positions of the ultrasonographic probe that provided an optimum longitudinal and transverse section of the GB were carefully marked on the skin with a permanent marker. These guiding marks were affixed. The longitudinal and transverse images of the GB were always taken at the same respiratory phase of the belly. Dogs were prepared by having their skin exteriorized through a skin incision made in the interscapular area, and sutured there with silk. After the operation, an elastic bandage dressing was placed on the dog to protect the wires from damage. The dogs were allowed access to food on the day after the surgery. Each animal was allowed a 10- to 15-day period of recovery before the experiments began. According to our experience, at this time no remarkable macroscopic changes in the shape of the GB can be found on ultrasonography.

Comparison of GB contractility in dogs equipped with force transducer implanted onto GB body and in unoperated animals

Two groups—unoperated and operated animals—each group consisting of four mongrel dogs, were examined. The experiments described below were repeated on separate days, once a day, two to three times on each dog. The data obtained for a given dog were averaged and the resulting "grand means" were subjected to further statistical analysis.

Meal-induced GB emptying.

The fasting GB volume was measured. Immediately thereafter the dogs were given their standard meal, consisting of 750g canned food \( \text{Fido} \); Quaker, Marseille, France) containing 21.7% dry matter, 7.7% protein, 4.5% fat, 6.9% carbohydrates, and 2.6% minerals, which they ate within 2–4 min. The mass of the meal was precise to within 10 g to provide a reproducible stimulus for GB contraction over repeated examinations. The meal was prepared and kept in a separate room until the time it was given. Only one dog stayed in the examination room at feeding time. The postprandial GB volumes were measured at 10-min intervals for 120 min (the beginning of the meal being taken as time 0).

Cerulein-induced GB contraction.

For cerulein i.v. infusions the dogs were permanently equipped with a catheter \( (\text{length} \ 60 \text{cm}, \text{external diameter} \ 1.5 \text{mm}, \text{internal diameter} \ 1.0 \text{mm}; \text{Haemocath ORX}, \text{Vygan, Ecouen, France}) \) inserted into the superior vena cava via the external jugular vein. Cerulein \( (\text{Takus, Farmitalia Carlo Erba, Milan, Italy}) \) was dissolved in normal saline \( (0.9\% \text{ sodium chloride}) \) and infused intravenously with an infusion pump \( \text{model} \ 99; \text{Razel Scientific Instruments, Stanford, CT, USA}) \). Cerulein infusion at stepwisely increasing doses. After the basal GB volume was measured, cerulein was infused i.v. at stepwisely increasing rates: 0.7, 2.2, 7.4, 22.2, and 66.5 pmol kg\(^{-1} \text{h}^{-1}\), each dose being administered for 10 min. The GB volume was measured at the end of each 10-min infusion interval just before the subsequent cerulein dose was begun.

Constant rate cerulein infusions. The basal GB volume was assessed, and then cerulein was infused i.v. for 1 h at a constant rate of 7.4 or 22.2 pmol kg\(^{-1} \text{h}^{-1}\). The GB